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The Influence of Redd Distribution and Microhabitat Availability on the Distribution and Abundance of Young-of-the-year Trout in the Green River, Utah

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THE INFLUENCE OF REDD DISTRIBUTION AND MICROHABITAT AVAILABILITY ON THE DISTRIBUTION AND ABUNDANCE OF YOUNG-OF-THE-YEAR TROUT IN THE GREEN RIVER, UTAH

by

Michael J. Buntjer

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Michael J. Buntjer

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ABSTRACT

The Influence of Redd Distribution and Microhabitat Availability on the Distribution and Abundance of Young-of-the-year Trout in the Green River, Utah

by

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Utah State University, 1992

Major Professor: Dr. Timothy Modde
Department: Fisheries and Wildlife

Redd distribution, redd density, and physical habitat were used to explain the distribution and abundance of young-of-the-year (YOY) brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in the Green River, Utah. The importance of variables at both a microhabitat and macrohabitat scale were assessed using stepwise regression analysis. Availability of cover (rock and vegetation) and proximity to spawning sites were the most important variables used to explain the distribution and abundance of YOY brown trout and rainbow trout. In addition, YOY brown trout and rainbow trout occupied specific microhabitats and showed patterns of use for particular depths, substrates, and cover. However, the importance of variables differed by year, indicating that variables other than those measured were also influencing their distribution and abundance. The results of my study indicate that variables at both a microhabitat and macrohabitat scale may be important in explaining the distribution and abundance of YOY trout in streams. Therefore, to better understand the habitat requirements of stream fishes and to better explain their distribution and abundance in streams future, studies may need to incorporate both physical habitat variables and variables affecting recruitment. (59 pages)

INTRODUCTION

Dispersal patterns of young-of-the-year (YOY) salmonids from spawning gravels to nursery habitats may help to explain their distribution in streams (Richards and Cernera 1989). In addition, the availability and distribution of nursery habitats may also influence YOY salmonid populations (Moore and Gregory 1988a). Bozek and Rahel (1991) found that YOY cutthroat trout (*Oncorhynchus clarki*) might not be present in areas with "suitable" microhabitat if these areas were not in close proximity to spawning sites, presumably because their movement from spawning areas was limited. Thus, if dispersal patterns of YOY salmonids from spawning sites to rearing areas were known, this might help to explain why stream sections with suitable microhabitat are unoccupied by YOY salmonids.

Movement of YOY salmonids from spawning gravels to rearing areas can be classified into three broad categories: (1) local or restricted movement consisting of dispersal within the natal environment, (2) downstream movement into a larger stream, a lake, or directly to sea, and (3) upstream movement into a lake (Raleigh 1971). Several authors have indicated that dispersal of YOY salmonids from spawning sites to nursery areas may be limited (e.g., Jenkins 1969; Stauffer 1972; Egglishaw and Shackley 1977, 1980; Northcote 1967, 1969; Rimmer 1985; Elliott 1986, 1987a; Hearn and Kynard 1986). However, studies have rarely considered the relation between dispersal from spawning sites and YOY salmonid distribution and abundance.

After an initial dispersal from spawning gravels (Jenkins 1969; Northcote 1978; Elliott 1986) there is typically limited movement of YOY salmonids during summer (Saunders and Gee 1964; Alexander and MacCrimmon 1974; Solomon and Templeton 1976; Milner et al. 1979; Mortensen 1977; Elliott 1986; Moore and Gregory 1988b). Movement during summer may range from a couple of meters to a few kilometers (Edmundson et al. 1968; Jenkins 1969; Trotter 1989; Richards and Cernera 1989). Though seasonal movements may occur (Elliott 1987b; Baltz et al. 1991), distribution patterns of resident salmonids in lotic systems are relatively stable (e.g., Northcote 1967, 1969, 1981; Hall and Knight 1981; Heggenes 1988a; Hesthagen 1988). In small streams, fish have spent their entire lives within relatively short reaches of a stream (Schuck 1943; Miller 1957; Le Cren 1973; Cargill 1980; Moore and Gregory 1988a). However, little quantitative information is available on the distribution and abundance of YOY salmonids in large rivers, particularly of resident species. To explain differences in YOY salmonid densities most studies have considered only habitat availability (Hall and Knight 1981; Fausch et al. 1988) or spawning density (Anderson 1983; Beard 1990).

Habitat models have been used to identify habitat requirements and to predict standing stock of stream fishes (Heggenes 1988b; Bozek 1990; Bozek and Rahel 1991). Many studies have demonstrated that microhabitat variables including water depth (e.g., Kennedy and Strange 1982, 1986; Shirvell and Dungey 1983), water velocity (e.g., Lewis 1969; Bachman 1984; Fausch 1984; DeGraaf and Bain 1986), substrate (e.g., Chapman and Bjornn 1969; Bohlin 1977; Rimmer et al. 1983, 1984), and cover (e.g., Lewis 1969; Wesche et al. 1987; Bisson et al. 1988; Heggenes and Traaen 1988) are important in explaining the distribution and abundance of trout in streams. Variables at different scales (e.g., temperature and discharge) may also influence where fish are found (Taylor 1988; Baltz et al. 1991). However, attempts to correlate standing stock of fish from available habitat often meet with limited success or with failure (Mather et al. 1985; Conder and Annear 1987; Orth 1987; Fausch et al. 1988; Hogan and Church 1989; Shirvell 1989).

Models that have been developed to predict fish abundance from habitat have the inherent assumption that habitat is limiting abundance rather than recruitment or movement. However, if movement of YOY salmonids from spawning gravels to nursery areas is local or restricted, stream sections without spawning sites may be limited by recruitment (Mundie 1974). Limited recruitment can affect habitat models by reducing the variation explained by variables in the models. In addition, if suitable rearing habitats are not in close proximity to spawning areas, abundance of YOY salmonids may also be limited by available habitat (Dolloff 1987). My study addresses the collective influence of redd distribution and habitat conditions on the distribution and abundance of YOY trout during summer. Specifically, the objectives of this study were to: 1) determine the microhabitats selected by YOY brown trout (*Salmo trutta*) and rainbow trout (*O. mykiss*) in the Green River, Utah, and, 2) assess the influence of redd distribution and microhabitat availability on their distribution and abundance.

STUDY AREA

This study was conducted in the Green River downstream of Flaming Gorge Dam in northeastern Utah (Figure 1). The study area, from the dam to below Taylor Flat bridge, was approximately 26.1 km. Daily discharge releases from Flaming Gorge Dam varied from 22.7 m^3/s to 118.9 m^3/s, but were higher and more varied in 1987 than 1988 (Modde et al. 1991). The river bed elevation ranged from 1705 m at Flaming Gorge Dam to 1660 m at Taylor Flat bridge. Surface water temperatures ranged from 2.2 - 6.0 C in winter to 12.0 - 19.0 C in summer.

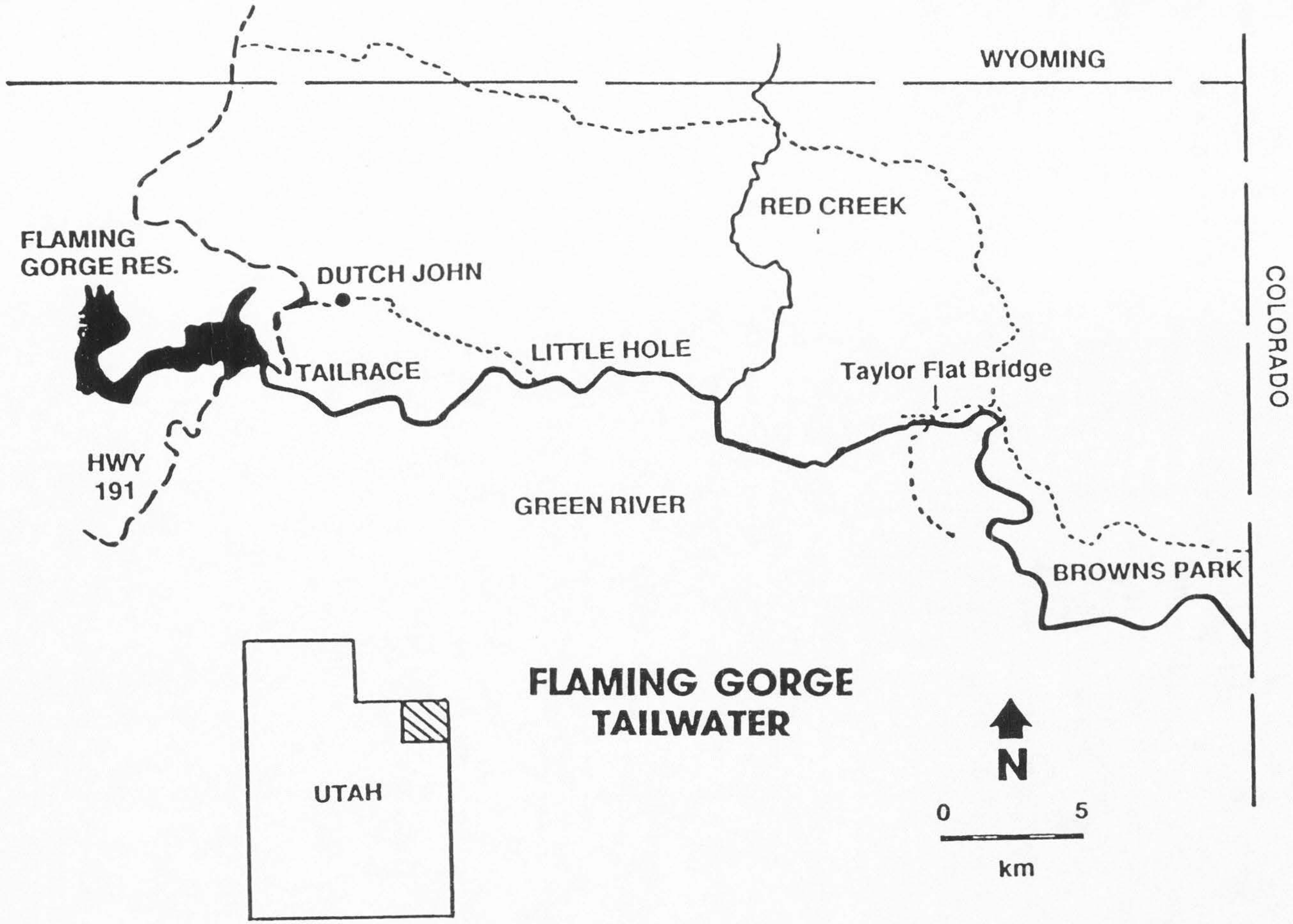

Figure 1.--Study site location in the Green River, Utah.

Rainbow trout, brown trout, cutthroat trout, and brook trout (*Salvelinus fontinalis*) were the predominant salmonids in the study area (Modde et al. 1991). Rainbow trout, cutthroat trout, and brook trout recruitment was augmented by annual stocking of hatchery-reared trout. Brown trout have not been stocked since 1967 (Bonebrake 1983) and were entirely self-sustaining. Brook trout and cutthroat trout are not included in this study because few YOY were observed.

METHODS

Young-of-the-year Trout Distribution and Abundance

The study area was divided into six reaches (Figure 2) based on major geomorphic features such as topography, geology, and gradient. A reach boundary represented either a change in stream gradient, cross-sectional profile, substrate type, or the confluence of the tailwater with a major tributary. The approximate lengths of reaches A through F were, respectively, 6.6, 3.7, 4.7, 2.7, 4.2, and 4.2 km.

Each of the six study reaches was delineated into 100 m sections. Both river banks in each section were assigned a number and represented two potential sample sites for collecting YOY trout. The number of potential sample sites ranged from 50 in the shortest reach (D) to 124 in the

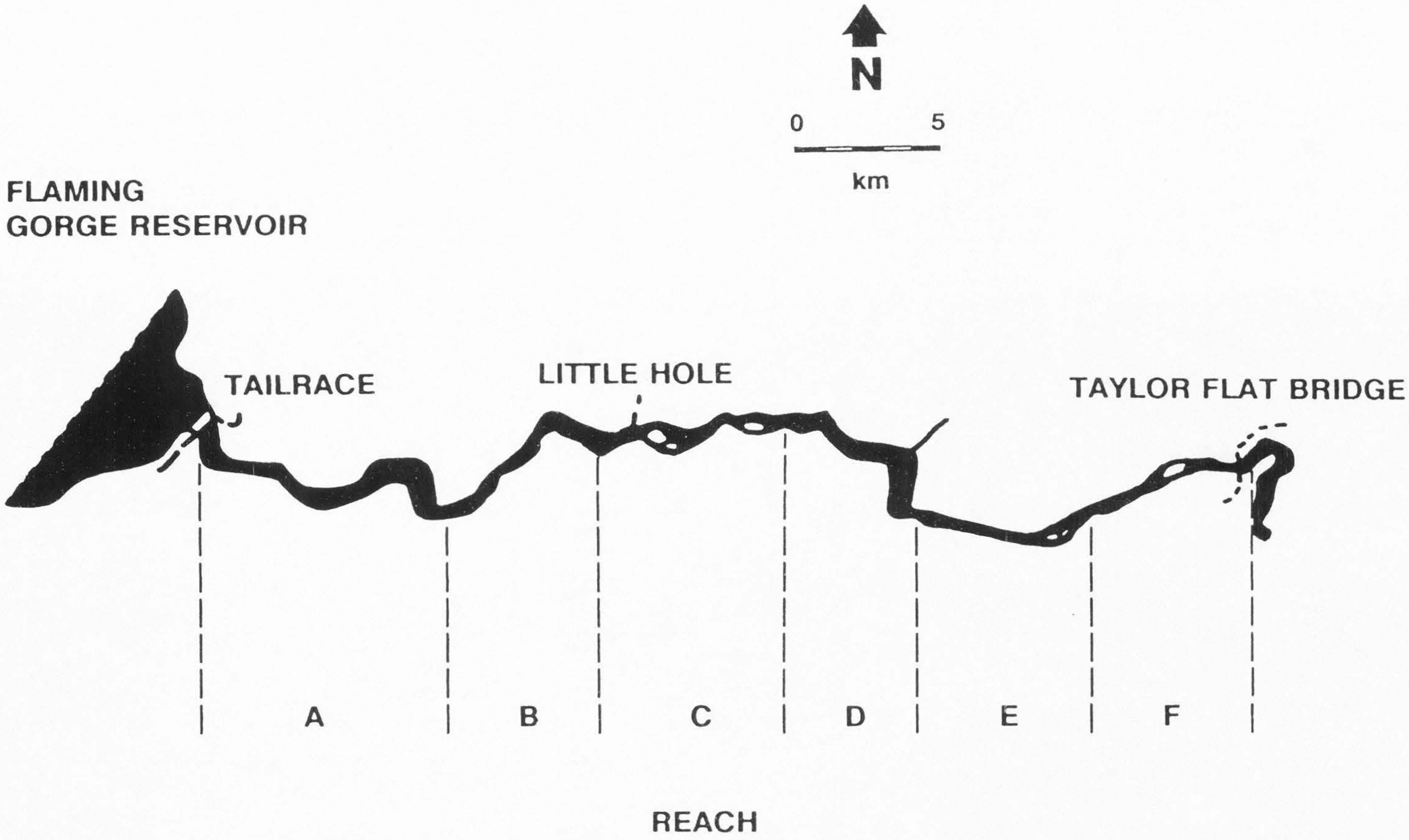

Figure 2.--Reach delineations, A through F, in the Green River, Utah, study area.

longest (A). The number of sites sampled in each reach was proportional to the length of the reach (Green 1979) and no sites were sampled more than once. All sites were selected at random using a random numbers table. To identify the site locations, a map traced and scaled from aerial photographs was used in the field.

Trout were sampled near shore during July and August 1987 and 1988. I defined near-shore areas as waters with a maximum depth of 0.6 m or a maximum distance from shore of 3 m. Near-shore areas were sampled because these habitats are most often occupied by YOY salmonids (e.g., Lindroth 1955; Chapman 1962, 1966; Lister and Genoe 1970; Bohlin 1977; Symons and Heland 1978; Campbell and Neuner 1985; Carty 1985; Sheppard and Johnson 1985). Discharge from the dam was constant during sampling to eliminate potential confounding effects (e.g., stranding or habitat displacement) from fluctuating discharge. All samples were collected between 0800 and 1800 hours.

Trout were captured by electrofishing (Model BP-1C Coffelt backpack electroshocker) in an upstream direction in the shallow, near-shore waters using one pass. I assumed the one pass estimate provided a good relative measure of fish abundance based on observations of fish escapement during preliminary YOY sampling. The trout were counted, identified to species, and length measured to the nearest millimeter (FL in 1987 and TL in 1988).

Fish density at each site was determined for both species by dividing the number of fish captured by the measured area of the site. These values were used in an ANOVA (General Linear Model [GLM] three-way split plot design) to determine if there were significant differences in fish densities among species, reaches, and years.

Young-of-the-year Trout Microhabitat Use, Availability, and Electivity

For each fish captured, the first point of observation was marked with a small float. Marking the first point of observation rather than the point of capture should minimize the effects of "electropushing" on fish location (Hearn and Kynard 1986; Heggenes 1988a). At each marker, total water depth, mean water column velocity, cover type, and dominant substrate size were recorded. Water depth was measured to the nearest 1.5 cm. Mean water column velocity was measured at 0.6 of the water depth measured from the water surface (Platts et al. 1983). Dominant substrate size and cover type within a 0.5 m radius of the point of capture was visually estimated. Dominant substrate size was defined using a modified Brusven substrate index (Bovee 1982) (Table 1). Cover was defined as refuge from predators, high water velocities, or both (Table 1).

Microhabitat measurements of total water depth and mean water column velocity and visual estimates of dominant substrate size and cover type recorded at individual capture

Table 1.--Classification of substrate sizes (using a modified Brusven substrate index) and cover types used in the study of young-of-the-year brown trout and rainbow trout habitat in the Green River below Flaming Gorge Dam, summers 1987 and 1988.

Cover type	Substrate size (mm)
No cover	Fines (<4)
Aquatic, emergent, or terrestrial vegetation partially or wholly submerged	Gravel (4-75)
River substrate large enough to be used by YOY trout as cover	Cobble (76-300)
Woody vegetation wholly or partially submerged or extending into the water from the bank	Boulder (>300)
Other cover	

sites were pooled by species for the entire sampling period. Pooling the data allowed for general comparisons of microhabitat use and availability for both species and calculation of electivities.

Electivities (*D*) for mean water column velocity, water depth, substrate, and cover were calculated from the formula of Jacobs (1974):

$$D=\frac{r-p}{r+p-2rp}$$

where r is the proportion of resource used by the fish and p is the proportion of resource available in the environment. Microhabitat availability was determined from five transects in each of the 100 m sample sites. Transects were spaced 20 m apart and oriented perpendicular to shore, beginning 10 m in from either end of the site boundaries. Transect lengths varied with water depth and ranged from 0 to 3 m as defined earlier for near-shore areas. Habitat variables measured included mean water column velocity, dominant substrate size, and cover. Variables were measured at 30 cm intervals along each transect. Water depth was measured at 0.25, 0.50, and 0.75 of the transect length. Surface water temperature (C) was recorded once at each sample site. The total area (m^2) of each sample site was calculated by multiplying the mean width of the five transects by 100 m.

For each sample site, the mean and the coefficient of variation (CV) were calculated for water depth and mean water column velocity. The percentage of available substrate sizes and cover types (from Table 1) was also calculated. These values were used as independent variables in a stepwise multiple regression analysis with fish density as the dependent variable.

Redd Distribution and Abundance

Trout spawning activity was determined by counting redds. Redd counts were made from 100 m above the Tailrace boat launch (Reach A) to 100 m below Taylor Flat Bridge (Reach F). In fall 1987 and spring 1988, redds were located to identify trout spawning areas. In fall 1988 and spring 1989, redd counts were made every 2 weeks between October and December and March and May to determine redd densities. To prevent multiple counts of the same redds, each redd observed was marked with a painted rock. Redd abundance for fall 1988 and spring 1989 was determined for each 100 m section where spawning activity occurred.

Although a fall spawning strain of rainbow trout was observed in the study area, individual fall-spawned redds could not be identified by species. In addition, rainbow trout and cutthroat trout redds could not be separated in the spring redd counts. Therefore, for the redd counts, all fall-spawned redds were counted as brown trout redds and all spring-spawned redds were counted as rainbow trout redds. By summarizing the redd count data this way, the number of redds included in the analysis for brown trout in the fall and rainbow trout in the spring were overestimated. However, because these species used the same areas for spawning, the data were assumed to provide a good relative measure of redd distribution and abundance for both species.

Young-of-the-year Trout Movement

A 600 m site near Devil's Island in Reach C (Figure 3) was selected in summer 1989 to monitor dispersal patterns and movement of YOY trout from a known spawning location. This site was chosen for two reasons: (1) it had sufficient

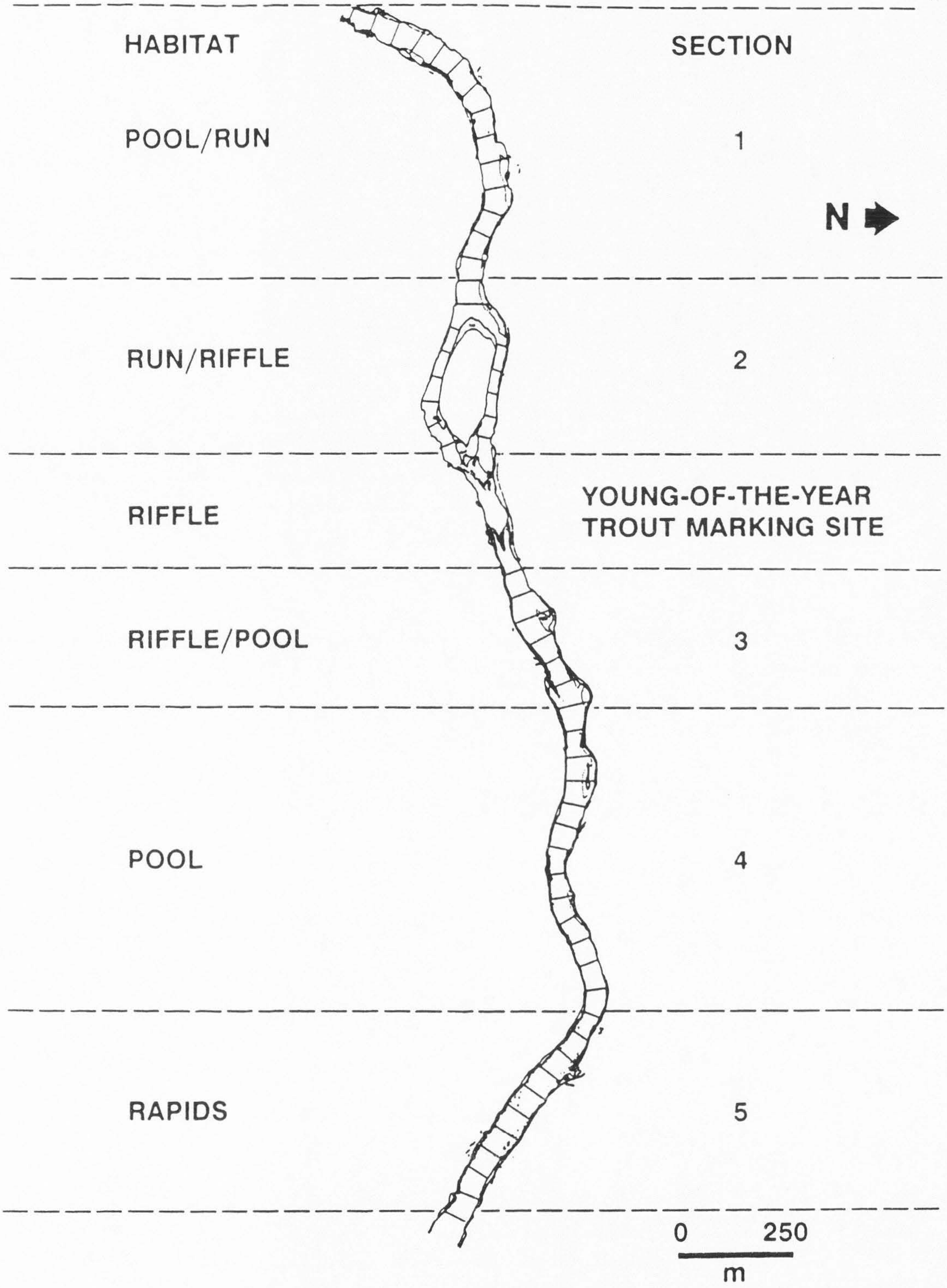

Figure 3.--Study sections, 1 through 5, above, within, and below the Devil's Island spawning site in the Green River, Utah.

numbers of both YOY brown trout and rainbow trout to mark and recapture and, (2) YOY trout could be easily attributed to redds in this site because of its isolation from other spawning areas. The lower 204 m of the 600 m spawning site was electrofished along the north river bank where spawning occurred. Captured trout were identified to species, measured to the nearest millimeter (TL), marked with an adipose fin-clip, and released near shore in the area in which they were caught.

Young-of-the-year trout were marked approximately one to four weeks following peak emergence (Buntjer 1991). Fall-spawned YOY brown trout (mean size TL of 36 mm, n=1,077) and rainbow trout (mean size TL of 37 mm, n=17) were marked 6-8 June. Spring-spawned YOY rainbow trout (TL<55 mm) were marked 26-29 July (mean size TL of 42 mm, n=323).

The river upstream and downstream of the 204 m marking site was delineated into five sections (Figure 3) based on macrohabitat features including runs, riffles, pools, and rapids. A section boundary represented a change in either macrohabitat (i.e., a riffle, run, pool, or rapid), stream gradient, or both. The approximate lengths of sections 1 through 5 were, respectively, 700, 400, 300, 650, and 500 m.

Each section was further divided into 50 m subsections with both river banks representing a potential paired-sample site for collecting YOY trout. The number of potential sample sites ranged from 6 in the shortest section (3) to 14 in the longest (1). The number of sites sampled in each section was proportional to the length of the section (Green 1979). Eight paired sites (two in sections 1, 4, and 5, and one site in sections 2 and 3), selected using a random numbers table, were sampled bi-weekly from 19 June through 16 August (40 total sites). This design allowed me to monitor the direction and distance moved by marked fish from the 204 m marking site and to compare fish abundance by section and river bank.

At each 50 m sample site, the trout were counted, identified to species, measured to the nearest millimeter (TL), and released near shore in the area in which they were captured. In addition, the distance upstream or downstream from the 204 m marking site was determined for each fish recaptured with an adipose fin-clip.

A GLM one-way ANOVA was used to determine if there were significant differences in YOY trout abundance (number of fish per 50 m) among sections upstream and downstream of the Devil's Island spawning site. The Least Squares Means (LSM) procedure (SAS Institute 1988) was used to determine which mean values were different. In addition, a paired *t* test was used to evaluate differences in YOY trout abundance by shore.

Young-of-the-year Trout Regression Modeling

Fish density (number of fish per m^2) was regressed, as the dependent variable, in a stepwise multiple regression analysis (SAS Institute 1988). The regression analysis included 12 and 14 independent variables, respectively, for 1987 and 1988 data (Table 2). Mean water column velocity and CV velocity were not included in the 1987 regression analysis because of sampling errors in the first two weeks of data collections. In addition, the first two weeks of data collections in 1987 were not included in the combined 1987 and 1988 regression analysis. Probability values greater than 0.15 were not considered to be significant in the models.

RESULTS

Young-of-the-year Trout Distribution and Abundance

Twenty-two percent of the length of both river banks in the study area were electrofished for YOY trout in 1987 and 1988. A total of 455 brown trout and 1,011 rainbow trout were captured. In 1987, rainbow trout accounted for 91.6% and brown trout 8.4% of the total fish captured. In 1988, rainbow trout accounted for 42.0% and brown trout 58.0% of the fish captured. Only three naturally recruited YOY brook trout and one YOY cutthroat trout were observed in 1988: none were observed in 1987.

Table 2.--Independent variables used in the stepwise multiple regression analyses. CV is coefficient of variation, YOY is young-of-the-year.

Independent variable
Water depth (cm)
CV water depth
Mean water column velocity (cm/s)(1988 and 1987/1988 analyses)
CV velocity (1988 and 1987/1988 analyses)
Substrate
Percent fines (<4 mm)
Percent gravel (4-75 mm)
Percent cobble (76-300 mm)
Percent boulder (>300 mm)
Cover
Percent vegetative
Percent rock
Percent rock and vegetation combination
Percent total cover
Surface water temperature (C)
Redd density (number of redds located upstream 1.6 km of each YOY trout sample site)

There was no significant difference in total YOY trout densities between 1987 ($0.056/m^2$) and 1988 ($0.055/m^2$) ($P \leq .459$) (three-way split-plot ANOVA). However, there were significant differences in mean trout densities by species in both 1987 and 1988, and by reach in 1988 (Table 3). There were also significant interactions of species by reach, species by year, and species by reach by year (Table 3). The significance of those interactions was due

Table 3.--Results of three-way split-plot ANOVA comparing rainbow trout and brown trout densities (number per m^2) by reach during summers 1987 and 1988.

Factor	df	MS	F-ratio	Significance
Reach (1987)	5	.00653	1.718	$P \leq 0.163$
Sites/Reach	54	.00380		
Species	1	.05816	31.609	$P \leq 0.000$
Reach*Species	5	.00646	3.511	$P \leq 0.010$
Error	54	.00184		
Reach (1988)	5	.01600	9.091	$P \leq 0.001$
Sites/Reach	42	.00176		
Species	1	.00529	14.694	$P \leq 0.001$
Reach*Species	5	.00382	10.611	$P \leq 0.001$
Error	42	.00036		
Year (1987/1988)	1	.00174	0.604	$P \leq 0.459$
Reach	5	.01987	6.899	$P \leq 0.001$
Year*Reach	5	.00372	1.292	$P \leq 0.284$
Pooled Error	97	.00288		
Species	1	.01135	9.619	$P \leq 0.003$
Year*Species	1	.04622	39.169	$P \leq 0.000$
Reach*Species	5	.00486	4.119	$P \leq 0.003$
Reach*Species*Year	5	.00513	4.347	$P \leq 0.002$
Pooled Error	97	.00118		

primarily to the shift in species composition between years. Mean densities of YOY brown trout and rainbow trout were highest in Reach D during both years (Figures 4a and b).

Young-of-the-year Trout Microhabitat Use, Availability, and Electivity

Young-of-the-year brown trout and rainbow trout occupied similar microhabitats in the Green River. Approximately 75% of all trout were collected in water depths between 15 and 45 cm (Figure 5a). Approximately 63%

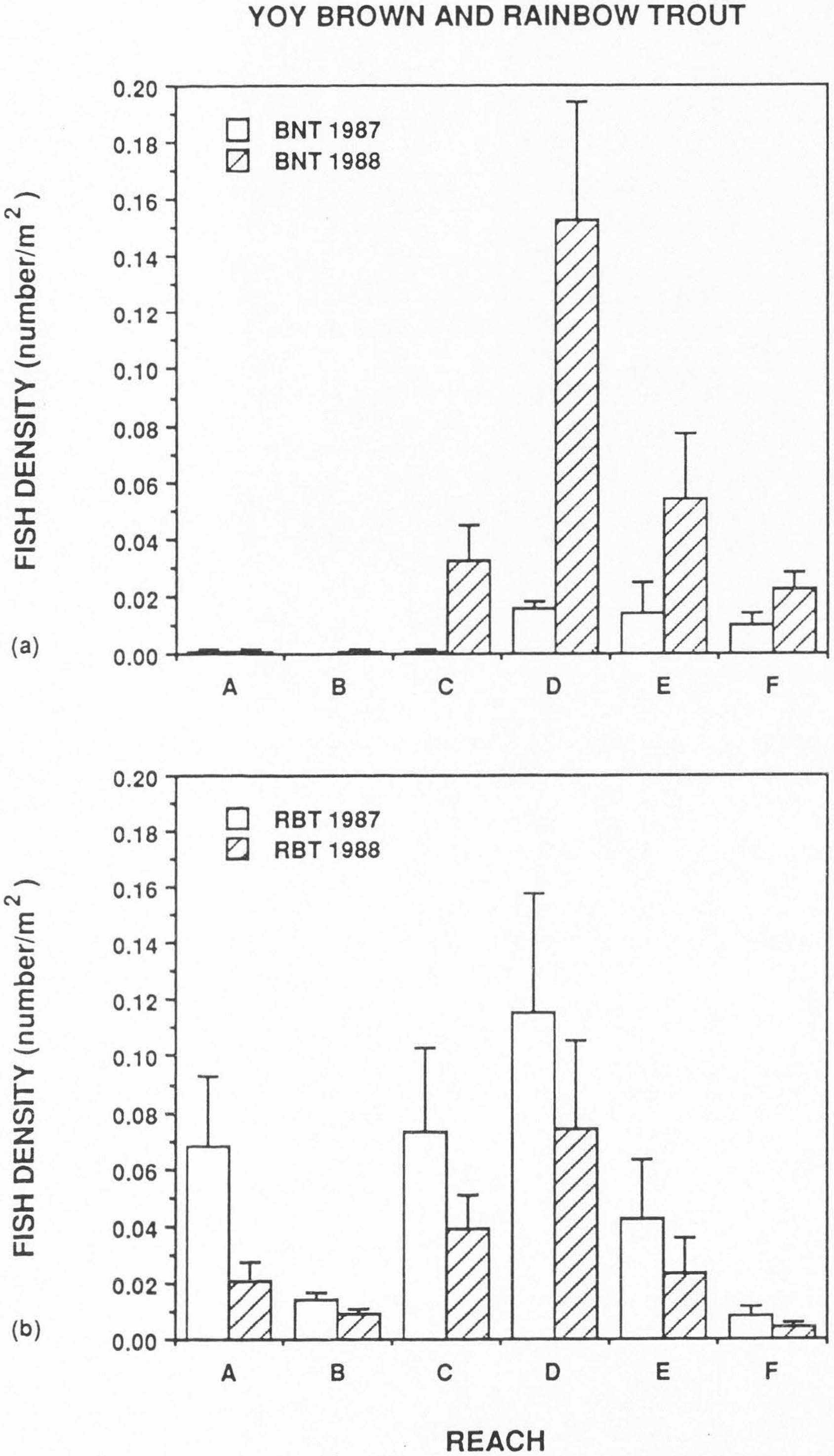

Figure 4.--Mean densities (number per m^2) of YOY (a) brown trout and (b) rainbow trout by reach during summers 1987 and 1988. BNT = brown trout, RBT = rainbow trout. Vertical bars are +SE.

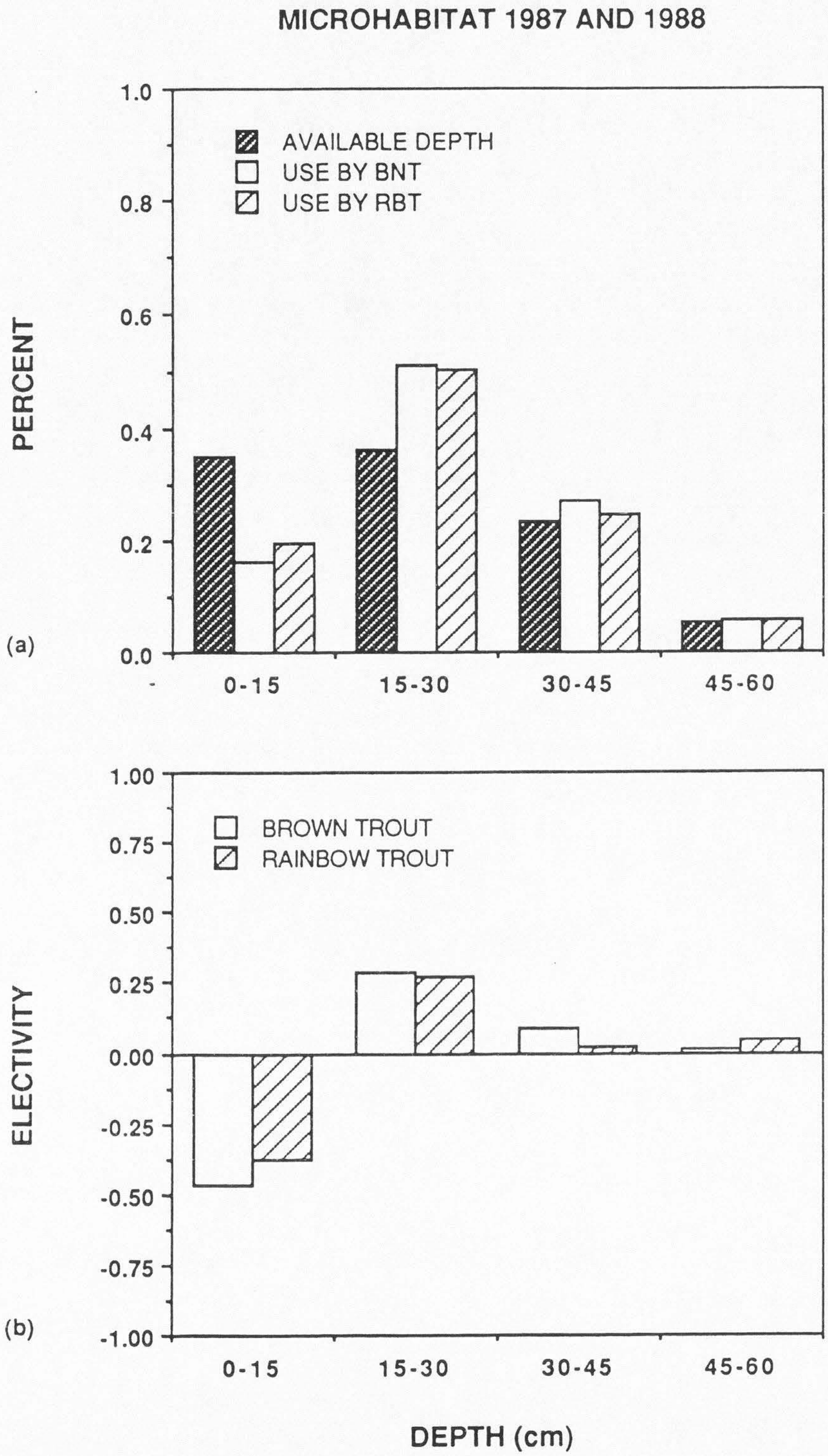

Figure 5.--(a) Use and availability of water depths occupied by YOY brown trout and rainbow trout in the Green River, Utah, during summers 1987 and 1988, and, (b) calculation of Jacob (1974) electivity values. BNT = brown trout, RBT = rainbow trout.

of brown trout and 66% of the rainbow trout were captured where mean water velocities were less than 5 cm/sec (Figure 6a). Ninety-nine percent of the brown trout and 96% of the rainbow trout were captured over substrate dominated by fines, cobble, and boulders (Figure 7a).

Cover of all types was present at 99% of brown trout and 94% of rainbow trout capture sites (Figure 8a). Sixty percent of brown trout and 71% of rainbow trout were captured at sites with one cover type and 36% and 21%, respectively, were captured at sites with two cover types. The cover combination of rock and vegetation had the highest relative use of all cover types: use was 36% for brown trout and 21% for rainbow trout. *Cladophora* spp. was the predominant vegetation.

Young-of-the-year brown trout and rainbow trout showed patterns of microhabitat use for all variables except mean water column velocity. Both species had strong positive electivities ($\geq$0.50) for the cover combination of rock and vegetation, and strong negative electivities ($\leq$-0.50) for areas without cover (Figure 8b). Both species had moderate negative electivities (>-0.50 but <-0.25) for areas with water depths less than 15 cm (Figure 5b). Brown trout had strong negative electivity for areas high in percent gravel (4-75 mm) while rainbow trout had strong negative electivities for areas high in percent fines (<4 mm) (Figure

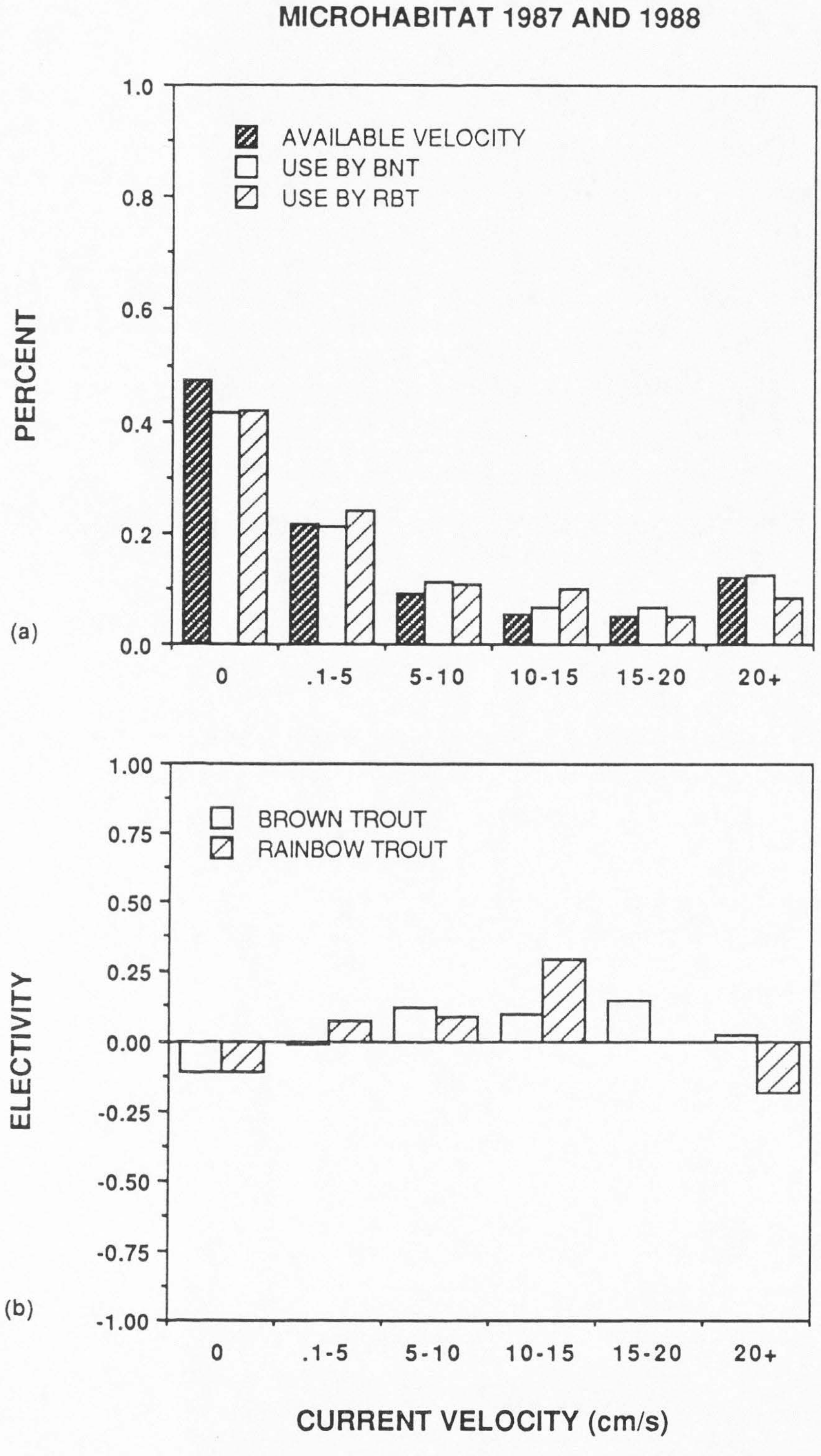

Figure 6.--(a) Use and availability of mean water column velocities occupied by YOY brown trout and rainbow trout in the Green River, Utah, during summers 1987 and 1988, and, (b) calculation of Jacob (1974) electivity values. BNT = brown trout, RBT = rainbow trout.

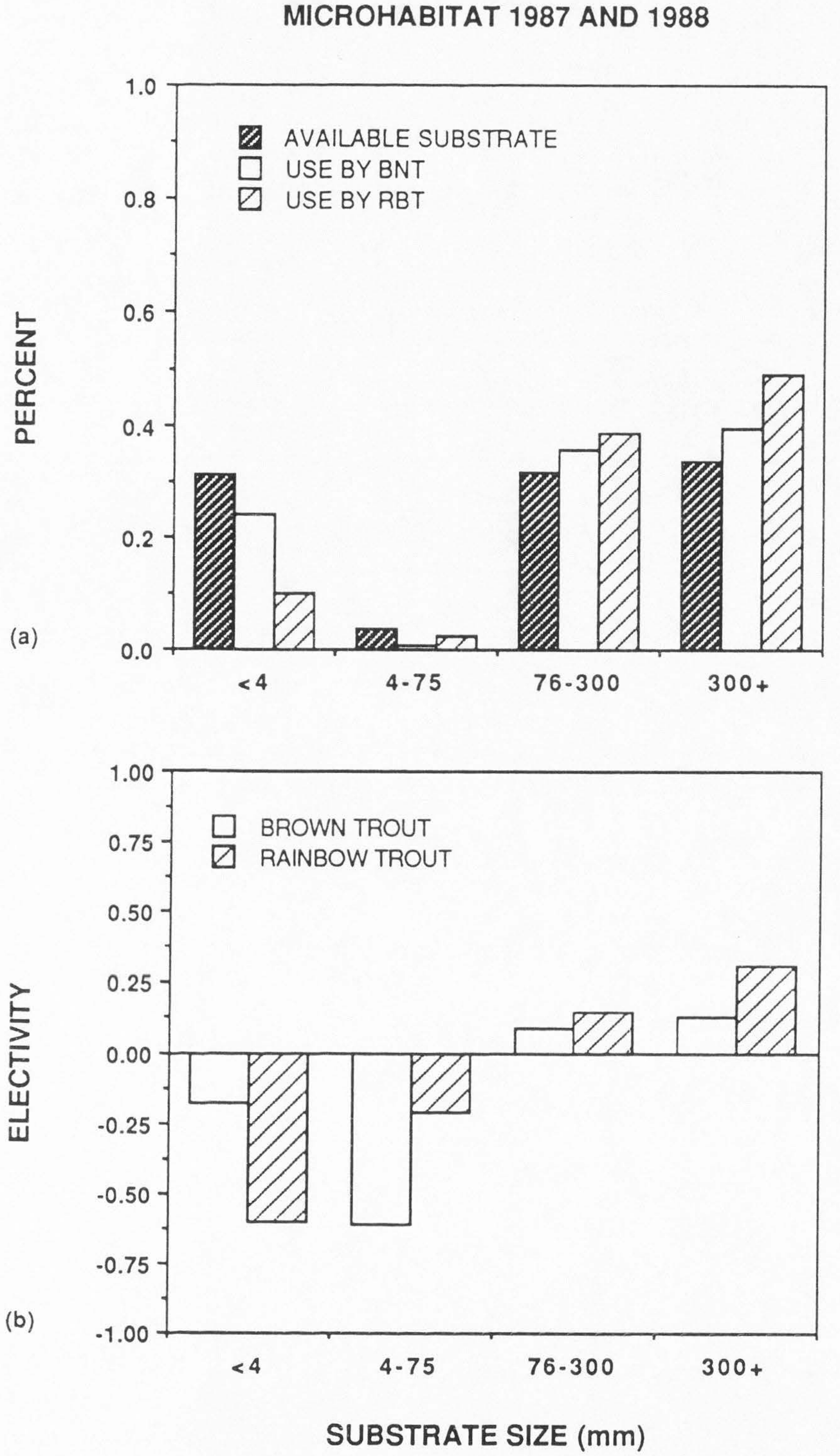

Figure 7.--(a) Use and availability of substrates occupied by YOY brown trout and rainbow trout in the Green River, Utah, during summers 1987 and 1988, and, (b) calculation of Jacob (1974) electivity values. BNT = brown trout, RBT = rainbow trout. Classification of substrate sizes are shown in Table 1.

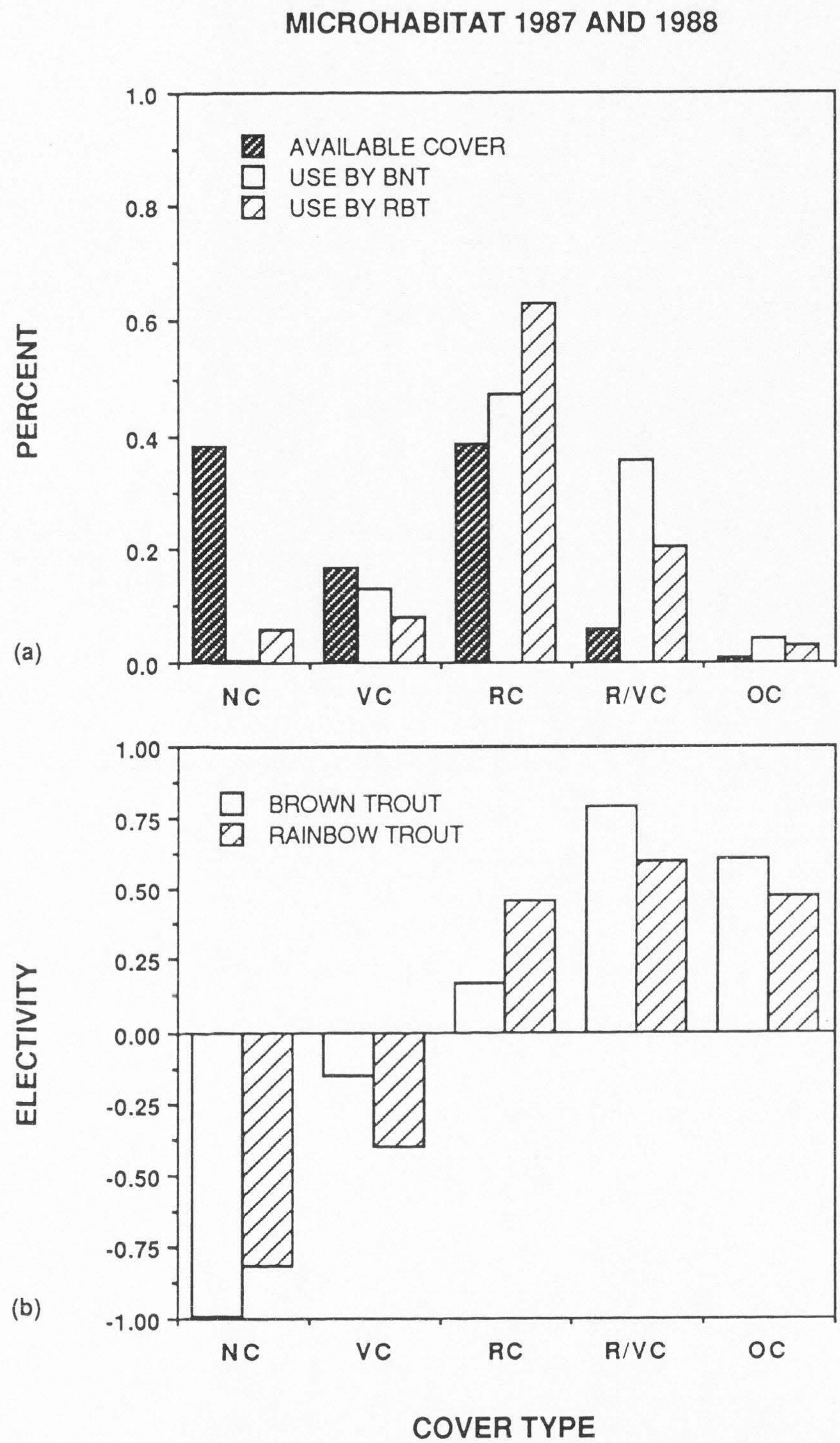

Figure 8.--(a) Use and availability of cover types occupied by YOY brown trout and rainbow trout in the Green River, Utah, during summers 1987 and 1988, and, (b) calculation of Jacob (1974) electivity values. BNT = brown trout, RBT = rainbow trout. NC = no cover, VC = vegetative, RC = rock, R/VC = rock and vegetative, and OC = other cover.

7b). Gravels usually coincided with areas of higher water velocities and limited cover (personal observation). Rainbow trout also had moderately positive electivity (>0.25 but <0.50) for areas high in percent boulder (Figure 7b) and percent rock cover (Figure 8b).

Redd Distribution and Abundance

Spawning sites were observed in all reaches in fall 1987 and 1988, and spring 1988 and 1989. Rainbow trout spawning was observed in all six reaches during both fall and spring of both years. However, positive identification of brown trout redds (i.e., fish present on redds) was observed only in reaches C, D, and E. Therefore, it is possible the fall redd count data did not provide a good relative measure of brown trout spawning locations in all reaches, particularly reach A where spawning was abundant. The total number of redds observed was higher during spring than fall (Figure 9a). Because fall 1987 and spring 1988 data were used only to identify trout spawning areas, direct comparison between years could not be made. Relative to YOY trout sample sites, redd densities in the fall were highest in reaches C and D and highest in spring in reaches A, C, and D (Figure 9b).

Young-of-the-year Trout Movement

There were differences in the mean abundance (number per 50 m) of brown trout ($P<.007$) and rainbow trout ($P<.01$)

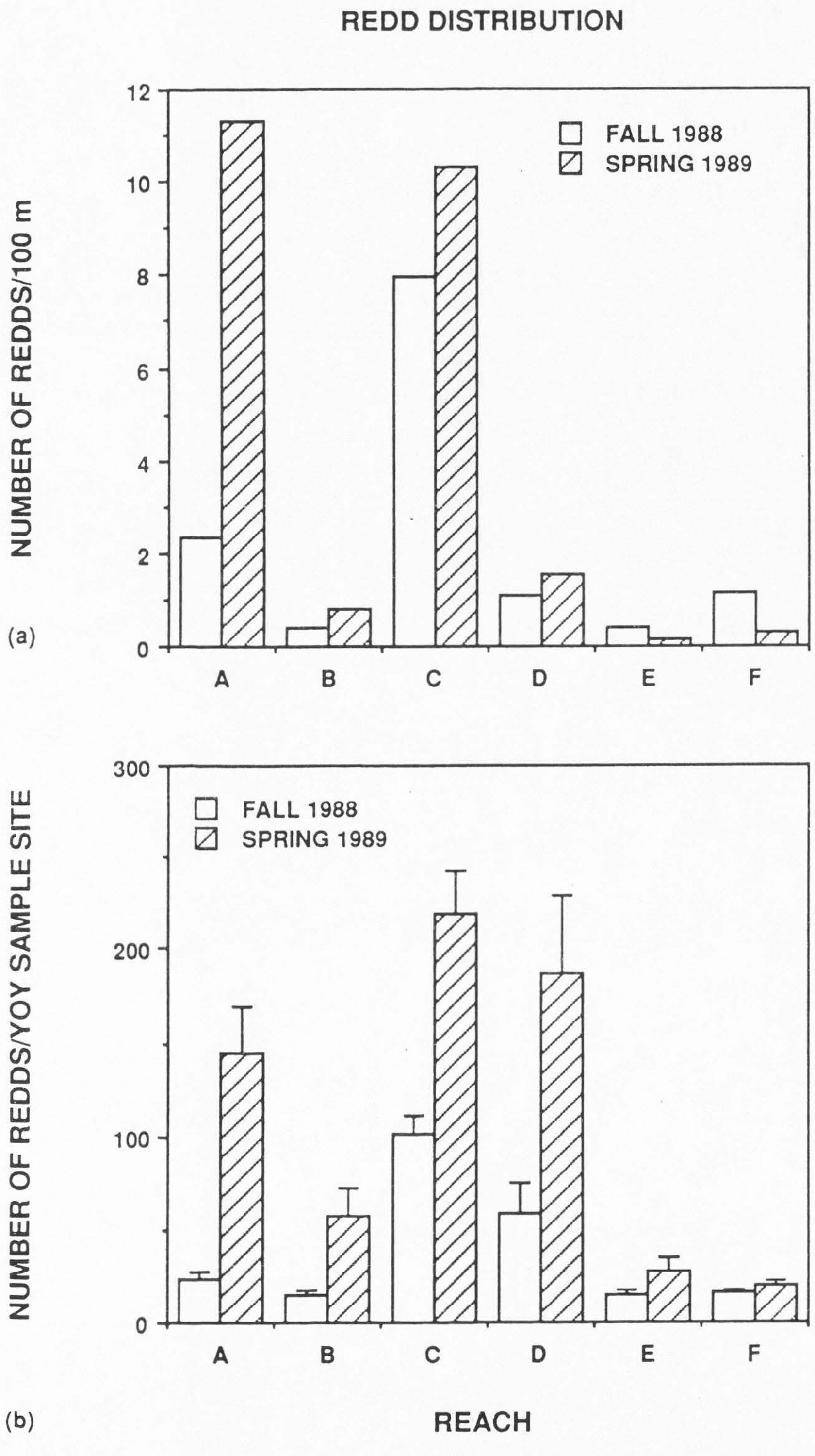

Figure 9.--(a) Mean number of redds per 100 m observed during fall 1988 and spring 1989 and, (b) mean number of redds located upstream 1.6 km of each YOY trout sample site in the Green River, Utah. Vertical bars are +SE.

Table 4.--Results of one-way ANOVAs comparing rainbow trout and brown trout abundance (number per 50 m) by section near Devil's Island during summer 1989.

Factor	df	MS	F-ratio	Significance
Rainbow trout	4	642.75	3.57	$P \leq 0.0102$
Error	75	180.18		
Brown trout	4	33393.93	3.84	$P \leq 0.0068$
Error	75	8690.43		

among sections upstream and downstream of the Devil's Island spawning site in 1989 (ANOVA) (Table 4). Mean numbers of brown trout were higher in sections 3 (P<.04) and 4 (P<.0004) than section 1 (LSM) (Figure 10). Mean numbers of rainbow trout were higher in sections 2 (P<.02), 3 (P<.07), 4 (P<.0005), and 5 (P<.06) than section 1. Mean numbers of both brown trout (P<.0113) and rainbow trout (P<.0896) were lower in section 5 than section 4. Thus, mean numbers of YOY brown trout and rainbow trout were lowest in section 1 and highest 0 to 1.6 km downstream of the Devil's Island spawning site during summer (Figure 10).

The mean abundance of rainbow trout was higher (P>.0938) along the north river bank for all five sections combined in 1989, but not higher for brown trout (P>.7389) (t test). However, much of the difference in rainbow trout abundance was due to differences observed in section 2. The mean abundance of both species in section 2 was significantly higher on the north side of Devil's Island

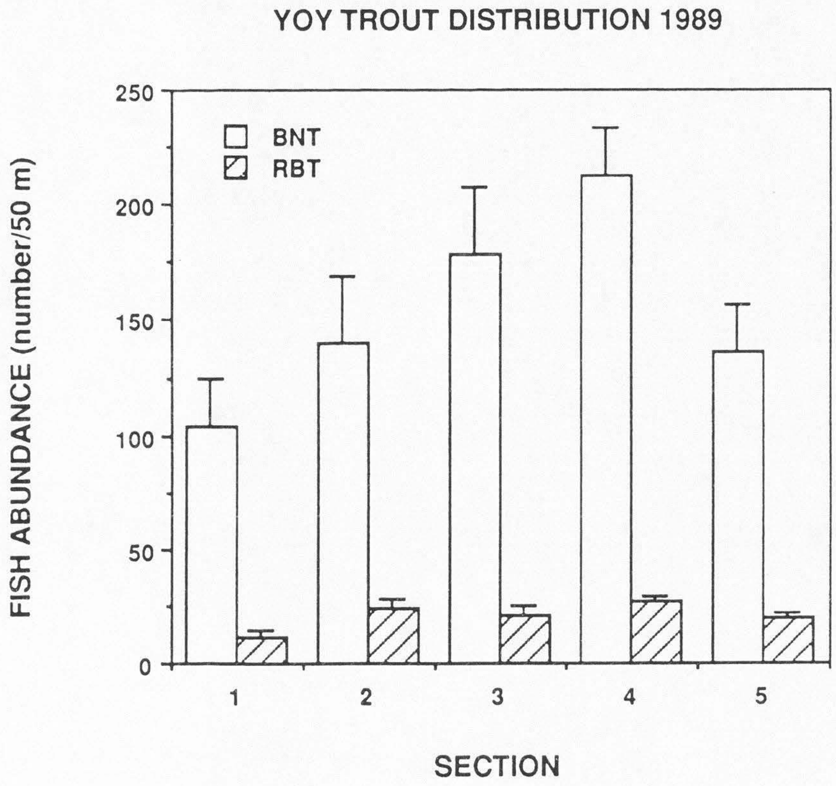

Figure 10.--Distribution of YOY brown trout and rainbow trout in study sections 1 through 5, above, within, and below the Devil's Island spawning site in the Green River, Utah, during summer 1989. BNT = brown trout, RBT = rainbow trout. Vertical bars are +SE.

Table 5.--Results of paired *t* tests comparing rainbow trout and brown trout abundance (number per 50 m) by shore near Devil's Island during summer 1989. N = number of sites sampled.

Species	Section	df	*T*	Prob>*T*
Rainbow trout	1 (N=10)	9	1.820	0.1020
	2 (N=5)	4	-3.873	0.0179
	3 (N=5)	4	0.687	0.5300
	4 (N=10)	9	-0.345	0.7380
	5 (N=10)	9	-2.969	0.0157
	All (1-5)	39	-1.717	0.0938
Brown trout	1 (N=10)	9	0.797	0.4459
	2 (N=5)	4	-3.838	0.0185
	3 (N=5)	4	1.168	0.3076
	4 (N=10)	9	-0.469	0.6504
	5 (N=10)	9	1.406	0.1933
	All (1-5)	39	0.336	0.7389

where spawning occurred (Table 5). Thus, the island likely restricted lateral shore-to-shore movement of YOY trout in this section. Rainbow trout were also higher in abundance along the north shore in sections 1 and 5 (Table 5).

Twenty of the 340 adipose-clipped rainbow trout and 92 of the 1,077 brown trout were recaptured. All 20 rainbow trout and 77 brown trout were recaptured in the original marking site (Figure 11). Thirteen brown trout were

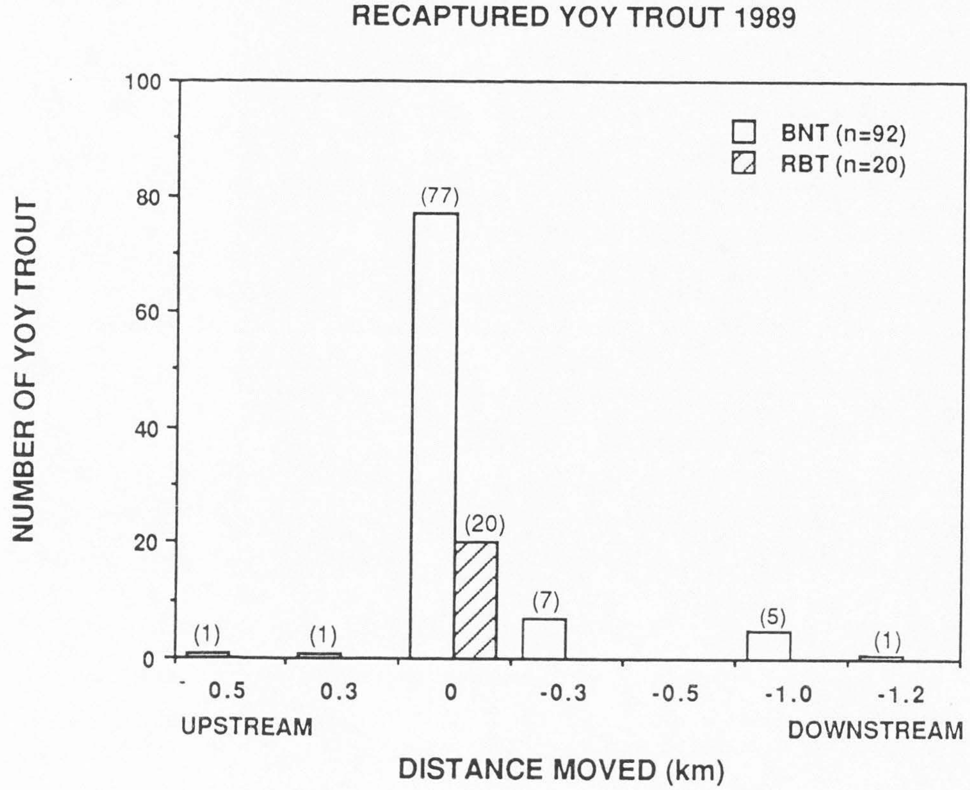

Figure 11.--Distances moved upstream and downstream by YOY brown trout and rainbow trout at time of recapture in the Green River, Utah, during summer 1989. The number of fish recaptured at each distance are shown in parentheses. BNT = brown trout, RBT = rainbow trout.

recaptured in downstream sections and 2 were recaptured in upstream sections of the original marking site (Figure 11).

Young-of-the-year Trout
Regression Modeling

The relative importance of variables in the stepwise regression models differed by year and, by combining years in the analysis the variability explained was reduced for both brown trout (Table 6) and rainbow trout (Table 7), with the exception of brown trout for 1987. The model variable that explained the most variation in rainbow trout densities was redd density (r^2=0.22, P=0.0001) in 1987 (Table 7). Redd density included the number of redds located upstream within 1.6 km of each YOY trout sample site. The cover combination of rock and vegetation (r^2=0.17, P=0.0015) explained the most variation in rainbow trout densities in 1988 (Table 7).

In 1987, when densities of brown trout were low (0.006/m^2), the only variable retained in the model was water temperature (r^2=0.05, P=.1053) (Table 6). However, in 1988 when brown trout densities increased 5 fold (0.031/m^2), the cover combination of rock and vegetation explained the most variation (r^2=0.40, P=0.0001). Other variables that were significant in the 1988 regression model but which explained less variation in brown trout densities included CV velocity (r^2=-0.12, P=0.0010), redd density (r^2=0.09,

Table 6.--Results of stepwise regression analysis using habitat and spawning variables as independent variables with brown trout density (number per m^2) as the dependent variable during summers 1987 and 1988. Signs in front of r^2 values represent direction of relationship, N = number of sites sampled, and CV = coefficient of variation.

Year	Variable	Partial r^2	Model R^2	F	Prob>F
1987	Temperature	+0.05		2.71	0.1053
(N=59)			0.05	2.71	0.1053
1988	% Cover (rock and vegetation)	+0.40		51.26	0.0001
(N=48)	CV velocity	-0.12		12.66	0.0010
	Redd density	+0.09		11.86	0.0013
	% Fines (<4 mm)	+0.08		15.92	0.0003
	Mean water velocity	+0.03		4.66	0.0367
	% Cover (total)	+0.02		2.68	0.1092
			0.74	17.12	0.0001
1987/1988	% Cover (rock and vegetation)	+0.18		29.42	0.0001
(N=83)	% Cover (total)	+0.12		24.49	0.0001
	% Fines (<4 mm)	+0.10		28.72	0.0001
	CV velocity	-0.05		15.74	0.0002
	Redd density	+0.03		4.79	0.0318
	Temperature	+0.03		4.18	0.0445
	% Cover (vegetation)	-0.02		5.34	0.0236
			0.53	12.14	0.0001

P=0.0013), percent fines (r^2=0.08, P=0.0003), and mean water column velocity (r^2=0.03, P=0.0367). Thus, when brown trout densities were low, variation explained by the model was not significant. However, when brown trout densities increased, physical habitat variables and redd density explained a significant amount of variation in the model.

Table 7.--Results of stepwise regression analysis using habitat and spawning variables as independent variables with rainbow trout density (number per m^2) as the dependent variable during summers 1987 and 1988. Signs in front of r^2 values represent direction of relationship, N = number of sites sampled, and CV = coefficient of variation.

Year	Variable	Partial r^2	Model R^2	F	Prob>F
1987	Redd density	+0.22		16.71	0.0001
(N=59)	% Boulder	+0.08		6.10	0.0166
			0.30	11.94	0.0001
1988	% Cover (rock	+0.17		11.44	0.0015
(N=48)	and vegetation)				
	Redd density	+0.10		5.04	0.0300
	CV velocity	-0.09		9.01	0.0045
	% Cover (total)	+0.06		4.40	0.0418
			0.42	7.76	0.0001
1987/1988	Redd density	+0.09		8.34	0.0059
(N=83)	% Cover (total)	+0.05		5.57	0.0433
	CV velocity	-0.04		4.90	0.0441
	% Cover (rock	+0.03		2.61	0.1104
	and vegetation)				
			0.21	5.04	0.0011

DISCUSSION

Young-of-the-year brown trout and rainbow trout had distinct but widely overlapping distribution patterns and used similar microhabitats in the Green River. In particular, brown trout and rainbow trout were commonly found in reaches C, D, and E, and typically occupied areas with rock and vegetation cover. Cover types had the highest electivities of all microhabitats followed by substrate size, water depth, and mean water column velocity. In addition, microhabitat availability and proximity of spawning sites explained a significant amount of variation in YOY trout densities, except for brown trout in 1987. Though there were no significant differences in abundance of fish by year, there were differences by species: rainbow trout were most abundant in 1987 and brown trout were most abundant in 1988.

Cover and water velocity have often been described as the most important variables affecting habitat choice of trout in streams (Lewis 1969; Gatz et al. 1987; Heggenes and Saltveit 1990). In my study, cover appeared to be more important than water velocity. Perhaps water velocities along the stream margins were within the preferred limits used by YOY trout (Moore and Gregory 1988b). Although a relation between mean water column velocities and focal velocities used by YOY trout has been shown (Baltz et al. 1987, 1991), mean water column velocities may not adequately reflect velocities occupied by YOY trout (Hearn and Kynard 1986), and probably over-estimate the actual velocities used (Moyle and Baltz 1985). Based on my definition of cover, which included protection from velocity, the importance of velocity in the presence of cover may have been masked. This was potentially substantial because 99% of YOY brown trout and 94% of rainbow trout occupied areas with cover.

Though it is often difficult to separate the importance of individual habitat variables (Heggenes and Traaen 1988;

Heggenes 1988b), several studies have shown that water depth (e.g., Jenkins 1969; Lewis 1969) and substrate (e.g., Chapman and Bjornn 1969; Wesche et al. 1987) are often less important than cover and velocity in habitat choice by trout of all lifestages (Gatz et al. 1987). Morantz et al. (1987) and Heggenes and Saltveit (1990) suggested that use of particular depths and substrates is flexible and varies according to availability in conjunction with other variables (Bjornn 1971). Heggenes (1988b) suggested that water depth is more important in small streams, where suitable depths may be scarce, than in larger rivers. In the Green River there was limited use of areas high in percent fines by rainbow trout and areas high in percent gravel by brown trout. Areas high in percent fines and gravels may not provide the interstitial spaces necessary for refuge from high water velocities or protection from predators (Heggenes 1988b, 1988c, 1990). There was also limited use of depths less than 15 cm by both species, indicating that shallow water depths did provide suitable microhabitat in the Green River.

The high overlap in distribution and microhabitat use between brown trout and rainbow trout suggests the potential for competition (Gatz et al. 1987). However, high overlap is often a poor predictor of competition (Thompson 1982). For competition to occur, resource demand must exceed resource availability (Hearn and Kynard 1986). Among YOY salmonids, intensity of competition is generally density-dependent (Egglishaw and Shackley 1977; Gee et al. 1978; Symons 1979; Hearn and Kynard 1986). Given the low to moderate densities of brown trout and rainbow trout (0 - 0.42 fish/m^2 combined) in sites below the dam, it does not seem likely that competition for space was high in all reaches, presumably because their populations were not large enough to use all the available space.

Although brown trout and rainbow trout occupied specific microhabitats, their abundance and distribution in the Green River was affected by other factors, including dispersal from spawning sites. The dispersal of YOY trout from spawning gravels was limited (0 - 1.6 km) and predominately downstream. Other studies have shown similar dispersal by YOY salmonids in smaller streams (e.g., Solomon and Templeton 1976; Richards and Cernera 1989). However, little quantitative information is available regarding patterns of dispersal by YOY trout, particularly in large regulated rivers.

After an initial dispersal from spawning gravels, and fish had established residence along the river banks, there was typically limited movement of YOY trout during summer. Studies have indicated that salmonid populations consist of a small mobile and a large sedentary component (Funk 1955; Jenkins 1969; Mense 1975; Solomon and Templeton 1976; Milner et al. 1979; Hesthagen 1988). My recapture data support these results for the summer populations of YOY brown trout and rainbow trout in the Green River. Limited movement probably reflects the risks associated with moving to an unfamiliar area even if the quality of habitat is marginal or poor (Dolloff 1987). However, patterns of movement may vary between small and larger rivers (Bohlin 1978).

Carty (1985) found that YOY brown trout and rainbow trout were higher in abundance in the Missouri River along the same river bank where spawning occurred, indicating that movement from shore to shore was limited. Although dispersal and movements were typically downstream and most fish occupied sites near shore (personal observation), my data showed that movement was not confined to the stream margins, particularly by brown trout. Thus, the main channel, though not used as a nursery area, was not an apparent barrier to fish movement.

Interspecific interactions may have influenced dispersal patterns and distances moved by some YOY trout. Brown trout are an aggressive species and tend to dominate other salmonids in sympatry (Heggenes 1988b), including rainbow trout (Gatz et al. 1987). It is possible that rainbow trout exhibited local increased dispersal in areas where both species were most abundant, including where movement was monitored (reaches C and D). The distance of 1.6 km used in my analysis may have been an overestimate of the distance moved by rainbow trout in some reaches of the river. For instance, in reaches A and B where YOY brown trout densities were lowest, the sample sites with the three highest densities of rainbow trout were located less than 200 m downstream of spawning areas. Therefore, proximity to spawning sites may have been more important to rainbow trout distribution than was indicated by the regression analysis.

In the regression analysis, both microhabitat availability and proximity of spawning sites were important in explaining variations in YOY trout densities. Yet, the importance of microhabitats and spawning sites differed by year. In 1987, when rainbow trout were most abundant, redd density and percent boulder explained a significant amount of variation in rainbow trout densities, but only water temperature (a macrohabitat variable) was marginally significant for brown trout. In 1988, when brown trout densities were higher by a factor of 5, the variation explained by microhabitat (primarily cover) and redd density was significant for both brown trout and rainbow trout. The variation explained by specific habitat features may vary with changes in population density (Moyle and Baltz 1985; Rankin 1986). This may explain the differences in variation associated with habitat variables between years of this study. However, the total variation explained by the models and the change in species abundance between fall-spawned brown trout and spring-spawned rainbow trout indicates that other factors were affecting spawning success or recruitment of YOY trout.

Although the variation explained by temperature in the regression analysis was almost nonexistent, it was significant (r^2=.03, P<.05) in the combined analysis for brown trout. Temperature is known to influence microhabitat selection by salmonids (Baltz et al. 1991). However, its potential importance in this study may reflect the differences in flow regime (Moyle and Baltz 1985). Though flows were relatively low and stable during summer sampling, flows were higher and varied more in winter 1987 than winter 1988 (Modde et al. 1991). Populations of several YOY salmonid species are affected by flows of the preceding winter and spring (e.g., Anderson and Nehring 1985; Nehring and Miller 1987). In years following a mild winter and spring, with little high water, Moyle and Vondracek (1985) observed the highest numbers and biomass of rainbow trout and brown trout. Seegrist and Gard (1972) found that survival of spring-spawned rainbow trout fry increased in years following winter floods presumably caused by reduced competition from brook trout, a consequence of eggs being destroyed by flooding. However, when flooding occurred in May, rainbow trout eggs were destroyed and survival of brook trout was improved.

Discharge levels following fall 1986 spawning were higher on a mean daily average by 50% than during the same period in 1987 (USGS 1987, 1988). Daily discharge levels during May 1987, when peak emergence of brown trout occurred, were on average 33% higher than in May 1988 when brown trout densities were higher. "Flooding" did not occur during this study, but the higher and more varied discharge in 1987 may have influenced the potential of newly emergent YOY brown trout to establish and defend territories, thereby reducing their chances of survival. Thus, factors related to discharge may have been associated with differences in either spawning success or recruitment between 1987 and 1988.

Bozek and Rahel (1991) used a multi-level habitat analysis approach to explain differences in YOY cutthroat trout densities at both a microhabitat and macrohabitat scale. Their microhabitat analyses identified specific depths and velocities used by YOY cutthroat trout. However, their macrohabitat analysis revealed that suitable spawning habitat was needed to produce YOY cutthroat trout in stream reaches with suitable microhabitat. The results of Bozek and Rahel (1991) and my study indicate that without proximal spawning areas, it is unlikely that a relationship between standing stock of YOY trout and habitat area can be made.

Quality of habitat and proximity of spawning areas are both important in explaining the distribution and abundance of YOY trout in streams. Although YOY brown trout and rainbow trout did occupy specific microhabitats in the Green

River, the results of this study indicate that YOY trout did not disperse far from spawning sites during summer. Therefore, quality habitat in close proximity to spawning sites may be necessary for successful recruitment of YOY trout. Thus, models that include only habitat variables, particularly at one scale, may not adequately describe the distribution and abundance of resident YOY trout in streams (Bozek and Rahel 1991). In addition, factors influencing spawning success or recruitment must also be identified. This may help to explain why habitat variables and, therefore, habitat models do not consistently describe fish abundance in streams. To better understand the habitat requirements of stream fishes and to better explain their distribution and abundance in streams, future studies may need to incorporate both physical habitat variables and variables affecting recruitment.

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